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Proceedings for Session Two

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Changing Land Use Patterns at the Urban/Rural Fringe

Nancy Bockstael, University of Maryland B Summarization

Dr. Bockstael began by thanking and crediting EPA for its early support of her land use planning research. Dr. Bockstael also expressed her appreciation for the cooperation of the Office of Planning for the State of Maryland, and noted that this office had compiled an excellent land use database, making Maryland a good study site for land use researchers.

Dr. Bockstael commented that land use patterns have clearly become an emerging national political issue, despite the fact that it is still largely a matter of *local* policy control. Nevertheless, land use and urban sprawl have clearly affected elections on a much larger scale than locally. EPA has been involved with this issue, and it has a smart growth website (http://www.smartgrowth.org).

Dr. Bockstael noted a list of a handful of recent studies on sprawl, and noted the variety of sponsors of these studies, including the Bank of America, the Sierra Club, the Lincoln Land Institute, and the American Farmland Trust, to name a few. The reason that there are a spectrum of sponsors is because there are a spectrum of problems. Perhaps the leading problem is the public finance problem. Sprawl is defined as the proliferation of low-density residential development in a fragmented pattern. This has become expensive for local governments because of the high cost of providing public services to such a dispersed a population. Sprawl also chews up open space; the growth in land use for residential purposes is twice the rate of population growth. Sprawl also presents a potential ecological problem, but the effects of sprawl on the ecosystem are as yet unclear, and Dr. Bockstael has been working with ecologists and other environmental scientists to study the ecological implications.

The title of the paper that Dr. Bockstael presented was "Interacting Agents, Spatial Externalities, and the Evolution of Residential Land Use Patterns," by Dr. Elena Irwin and Dr. Bockstael. Dr. Bockstael acknowledged that most of the contribution to this paper was made by Dr. Irwin, one of Dr. Bockstael's former graduate students. The question addressed by this paper was: why do we see the emerging land use patterns of development? Dr. Bockstael showed a map of the Baltimore-Washington area that indicated areas of development, and noted that recent development has followed a speckled, dispersed pattern in the rural-urban fringe. The economics literature on the spatial pattern of urban development has predominantly been based upon the monocentric city model, which predicts that development will radiate outward from a city center. Allocating existing land use according to that theory produces a map which clearly does not approximate the observed pattern of development. As a second cut, the authors allocate land use according to the monocentric city model, but constrained by existing zoning and road networks (even though both these features of the landscape are realistically the result of the land use pattern not its determinant). The model based on the monocentric assumptions and these additional constraints more closely approximated the observed pattern, but was still lacking in explaining the fragmented pattern of growth in the rural-urban fringe.

New theoretical, spatial models are emerging in the economics and regional science literature. Based on work by individuals like Arthur, Krugman, and Page, interactions-based models motivate the evolution of land use pattern as the result of interactions among spatially-distributed agents. In the monocentric city model location matters only in relation to some city center, or some other exogenously-placed features of the landscape. The interactions-based models, however, allow agents' location decisions to be driven, not only by exogenous features of the landscape, but also locational decisions of other agents. This means that the evolution of the spatial structure is path-dependent. This also means that a variety of spatial structures can emerge from an initial set of conditions. The early literature in this area emphasized the formation of edge cities, and not the sprawl phenomenon, and generally lacked empirical evidence.

Some empirical work has been undertaken in the related literature of interactions in "social space". This literature, which draws upon the physics literature and uses particle interactions as an analogy, concerns itself with the question of how to aggregate up from micro level decisions that are spatially inter-related to a macro-level spatial pattern. The work by Irwin and Bockstael take off from these various literatures, as well as the econometric literature on an important identification problem. It is inherently difficult to disentangle the real interactions between agents and unobserved spatially-correlated heterogeneity.

The paper begins with a micro-level model in which agents optimize the timing of development, and then uses a cellular automaton model to simulate land use development patterns based on this model. The paper proceeds by empirical estimating and testing for endogenous interaction effects and then uses the results to compare predicted and actual patterns to see how closely the model can match the observed pattern.

The micro-level model of optimal timing of development is:

Develop in time T if:

$$V(i,T) - \sum_{t=0}^{\infty} A(i,T+t)d^{T+t} > 0 \quad \text{and}$$

$$V(i,T) \geq dV(i,T+1) + A(i,T)$$

where

$V(i,T)$ = one time net development returns from parcel *i* at time *T*

$A(i,t)$ = one period returns from undeveloped use of parcel *i*.

d = discount rate

The model also assumes that

$$V(i,T) = g\left[X(i), \gamma(T)\right]$$

where

$X(i)$ are parcel characteristics that tend to vary spatially but not temporally

$\gamma(T)$ are growth pressures that tend to vary temporally but not spatially

Incorporating the interaction effects requires consideration of how much of a surrounding neighborhood is developed, and the inclusion of a term to account for resulting repelling or attracting effects. This is accomplished in the following equation:

$$V(i,t) = g\left[X(i), g\,(t)\right] + l\,I(i,t)$$

where the latter term represents the interactive effect.

The micro model needs to be aggregated up to a macro level. Existing aggregation models, however, have a problem in that the aggregation from a micro level to a macro level only allows for positive effects; the effects are likely to be both positive and negative. Also, these models tend to characterize an equilibrium solution, whereas Dr. Irwin and Dr. Bockstael's interest lay in the dynamic process of the evolution of land use, not it's result when all possible rounds of development have occurred. Irwin and Bockstael thus developed their own cellular automaton model, and compare a land development simulation that assumes: (a) a monocentric city model, (b) a monocentric city model with additional endogenous but repelling interaction effects, and (c) a monocentric city model with both repelling and attracting effects. The latter led to the "clumpiness" characteristic of the observed pattern of development in the Baltimore-Washington area. From this experiment, Irwin and Bockstael concluded that incorporating endogenous interaction effects between agents, owners of parcels, *could* provide an explanation for the observed pattern of development.

Whether it does provide such an explanation is an empirical question. Irwin and Bockstael then set out to empirically test their theory using a hazard model, which is designed to explain a dynamic decision. The hazard model captures the probability that a parcel of land that has not yet been developed will be developed in the next time period. This model was estimated using data from the rural-urban fringe areas of several counties in the Baltimore-Washington area (Howard, Anne Arundel, Calvert, Charles and St. Mary's). These areas (Census block groups) have densities of at least 1000 per square mile, but are not in the immediate suburban areas of Washington, D.C. A proportional hazards model is used to avoid the problem of baseline hazard rates, and only the relative timing of parcels is considered.

In performing the empirical estimation, the problem of identification needed to be addressed. The problem is that one cannot observe all of the factors that affect parcel development, yet these factors are likely to be spatially correlated. The question then becomes: how does one distinguish true endogenous interaction effects from the unobserved spatially correlated effects? The solution was to adopt a Heckman and Singer bounding strategy. This works because the spatial correlation tends to be positive; this is a reasonable assumption, since close neighbors are likely to have similar characteristics. Thus, if the estimated interaction is negative (i.e., the neighbors are behaving differently), then the underlying endogenous interaction must truly be negative.

The dependent variable for the estimation was the probability of conversion to residential subdivision in a given year from 1991 to 1997. The estimation process utilized successively more inclusive combinations of the following independent variables:

Percent of neighboring land use within s^* (different distances, e.g., 800 meters or 1000 meters) in developed use

Percent of neighboring land use between s^* and s_{max} (1600 meters) in developed use

Commuting distance to central city

Dummy variable for prime agricultural land

Dummy variable for soils and slopes that raise construction costs

The empirical estimation found statistically significant repelling effect between similar land uses that became more significant as more explanatory variables (that are expected to be spatially correlated) were removed from the error and included in the hazard model estimation. This suggests that unobserved spatial heterogeneity tends to bias the interaction effect in the positive direction. The more of that spatial heterogeneity that can be included in the model rather than left unobserved, the more negative the estimated interaction effect becomes. Comparing predicted vs actual spatial patterns for a) a model without the interaction effects and b) one with those effects for a snapshot of Charles County provides convincing evidence that incorporating endogenous interactions effects generates more realistic predictions of the spatial pattern of land use change.

Dr. Bockstael concluded by offering the observation that analysis of growth control policies in the economics literature is restricted to models based on the monocentric city construct. Yet, that model is clearly inadequate in explaining the very growth patterns that growth control policies are being used to address.

Land Management with Ecological and Economic Objectives
--Working Paper*--

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Introduction

Public land managers are called upon to meet multiple, and sometimes, conflicting ecological and economics goals. The debate on how to promote both timber sales and continued survival of species such as the marbled murrelet, northern spotted owl and various stocks of anadromous salmon in the Pacific Northwest is a case in point.

Multiple ecological and economic objectives are often explicitly specified in laws and regulations governing agency behavior. The National Forest Management Act (NFMA) states that "fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired non-native vertebrate species in the planning area". The NFMA regulations define a viable population as "one which has the estimated numbers and distribution of reproductive individuals to insure its continued existence is well distributed in the planning area." NFMA further requires the Forest Service to develop alternative forest plans that "represent the most cost efficient combination of management practices examined that can meet the objectives established" and "alternatives shall be formulated to facilitate evaluation of the effects on present net value, benefits, and costs." Recently, an interdisciplinary Committee of Scientists (1999) released a report to the Secretary of Agriculture entitled "Sustaining the People's Lands: Recommendations for Stewardship of the National Forests and Grasslands into the Next Century". In this report the Committee recommended that "ecological sustainability provide the foundation upon which the management for national forests and grasslands can contribute to economic and social sustainability." Specifically the report states that the Forest Service needs to provide the ecological conditions necessary to protect the viability of selected focal species and of threatened, endangered and sensitive species. Despite the emphasis on ecological sustainability, the committee recognized the importance of traditional resource production such as timber harvest to the economic, social and cultural sustenance of many local communities.

Much of the existing research on land management has focused exclusively on economic issues (e.g., timber production or profitability) or exclusively on ecological issues (e.g., survival of a key species). Less common, until fairly recently, are studies that consider both ecological and economic issues in an integrated fashion. In this paper, we integrate models of wildlife population dynamics and timber economics to search for land management regimes that achieve ecological and economic objectives specified in terms of viability for a small set of target species and timber harvest volume. Land management decisions determine the habitat conditions that in turn influence species viability as well as determine timber harvests. We develop our approach and then apply it to a case study using GIS data on a forested landscape in the Central Cascades of Oregon. However, the approach itself is general and can be adapted to accommodate additional or different species, different geographic areas and additional or different land management activities and economic concerns.

Using the approach developed, we examine the production relationships between wildlife population survival and the value of timber harvest. Using our analysis we attempt to trace out the "production possibility set" showing the feasible combinations of species survival and the value of timber harvest. Ideally, we would solve for the production possibility frontier illustrating the maximum feasible combinations of survival probabilities and timber harvest. Doing so would illustrate the tradeoff between these goals under efficient land management.

Further, land management that generates results inside the production possibility frontier would be shown to be inefficient and the degree of inefficiency could be calculated. However, the problem of optimal landscape management is suitably complex that finding an optimal solution cannot be guaranteed. The decision space is huge as there are a large number of landscape units over which the analysis must be done. Further, the analysis is dynamic. When, as well as where, management actions are taken matters. In our analysis, we use a heuristic approach, specifically a simulated annealing algorithm, which generates a good solution without imposing overwhelming computational burdens.

In the next section of the paper we describe how the integrated model fits together and give details on each major component of the model. We then report results for a preliminary application of the model using GIS data for a region of the central Cascades in western Oregon. We discuss the results obtained so far and the direction of future work in the final section.

The Integrated Model

The objective of our study is to trace out the production possibility frontier showing the maximum feasible combinations of survival probabilities and timber harvest. Because the decision space grows exponentially with the number of land units and the time periods included in the analysis and the solution space is likely to be non-convex, we use heuristic algorithms to find good, though not necessarily optimal solutions to the problem. Therefore, the results that we find are close to but not necessarily on the production possibility frontier.

The general framework of the integrated model and the linkages between the components are illustrated in Figure 1. We begin with two pieces of information: the initial landscape that defines the land class of each land unit in the study area and species life history characteristics. These two pieces of information are fed into the wildlife population simulation model. Using a logit regression model, we compare the results using the wildlife population simulation model with several landscape indices and simple statistics calculated by the model to see whether there are computationally simple metrics that correlate with the results of the simulation model. We do this to simplify the process or searching for good solutions to the land management problem. We then use the simple metrics as the objective function in our search for optimal solutions. Upon finding land management solutions that score well with the simple metrics, we then use these solutions in the wildlife population simulation model and record the species viability and timber harvest scores. We repeat the analysis for various levels of timber harvest to trace out a production possibility frontier. We now describe each model component in more detail.

Species Population Simulation Model

We make use of a spatially explicit life history simulator called PATCH (a Program to Assist in Tracking Critical Habitat) (Schumaker 1998). PATCH reads GIS imagery directly and uses the data to link species' life history attributes and habitat preferences to the quality and distribution of habitats throughout the landscape. The PATCH model breaks species' life histories into three distinct components. Vital rates (survival and reproduction) determine the growth rate of a species, and are entered into the model using a population projection matrix (Caswell 1989). Habitat preferences describe an organism's use of habitat. Lastly, movement behavior governs a species' ability to navigate a landscape in search of high quality habitat. This approach allows

PATCH to link its projections of population viability to changes in landscape pattern, habitat quality, and habitat connectivity. Landscape pattern strongly controls the distribution of suitable breeding sites (and those ill-suited for breeding), while habitat quality determines what survival and reproduction rate will be experienced by the individuals occupying these sites. Habitat connectivity influences the ability of individuals to locate high quality habitat, which influences an individual's fitness as well as the ability of the species to re-colonize parts of the landscape that have experienced local extinctions.

PATCH includes stochastic demographic and environmental elements so that it is a stochastic rather than a deterministic simulation model. For any given landscape management profile, the model was run multiple times to generate a distribution of likely outcomes. We ran 100 population simulations of 100 years within the PATCH model for each alternative landscape. We define the probability of survival on a landscape as the number of times out of the 100 runs when the final population after 100 years is non-0.

Logit Regression Model

PATCH is a very detailed model that takes a long time to run. For computational reasons, there is utility in attempting to find an easily calculated index that correlates well with PATCH results. Therefore, we undertook the following analysis. For each of 50 different landscapes, a set of standard landscape indices and PATCH specific indices were calculated. We then used regression analyses to see whether combinations of these indices were highly correlated with species survival.

The indices we used were chosen from the existing literature on landscape patterns and PATCH model output. Indices were chosen to include some of the more popular indices that have been identified to impact wildlife dispersal and survival success. Indices analyzed include habitat patch area, habitat edge, habitat core area, fractal dimension and shape. Additionally, PATCH specific output was analyzed including the number of source breeding sites, the sum of habitat weights, and the number of expected source sites. Source breeding sites are defined within PATCH as sites with an expected dominant eigenvalue greater that 1.0. A dominant eignevalue greater than 1 indicates that birth and out-migration is expected to exceed mortality and in-migration for the site. For this application, the determination of source breeding status is dependent solely on the amount and quality of habitat within a given territory. Table 1 includes a list of the variables used in this a brief description of each.

In the regressions, the dependent variable was the proportion of times that the final population was non-0. Various combinations of the indices were included as regressors. Because the dependent variable is a proportion, it is bounded between 0 and 1. We used a logit model in the regression analysis. Define y_i as an indicator variable for survival of species i: $y_i = 1$ if species i survives and equals 0 otherwise. The probability of viability (P_i) given X_i (a vector of landscape indices) is:

$$P_i = \Pr(y_i{=}1 \mid X_i) = E(y_i \mid X_i).$$

The logit model takes on a particularly simple form:

$$\mathrm{Ln}(P_i/(1-P_i)) = X_i B$$

The logistic model is not designed to handle 0 or 1 results. Therefore, a small positive constant (.005 in our case) was added (subtracted) to 0 (1) results to handle these data points as suggested by Greene (1990).

Results for selected regressions are included in Table 2 as well as correlation coefficients for selected variables in Table 3. A regression including all relevant variables produced an R-squared of .870. Regressions including the number of source breeding sites and the sum of the eigenvalues for all source sites performed best in regressions including only a single variable (R-squared of .817 and .820 respectively). As can be seen in Table 3 the number of source sites and sum of eigenvalues for source sites are almost perfectly correlated creating results that are quite similar. Traditional landscape indices proved to have low explanatory power in predicting population survival. A regression including all of the traditional indices (habitat area, sum of habitat weight, habitat edge, core area, fractal dimension, and shape index) produced an R-squared of only .451. Based on these results of simulation runs on static landscapes, the number of source breeding sites was established as the objective function. Though the sum of the eigenvalues for all source sites performed slightly better, the number of source breeding sights is easier to calculate and has a more intuitive appeal.

Optimization Module

Maximization of an objective function where the choice variables are decisions on when and where to harvest is inherently a very large problem. Complete enumeration of the solution space for harvest-scheduling problems are exponential in number of harvest units and number of time periods analyzed. Standard optimization techniques such as integer programming become intractable as the number of harvest units or the number of time periods becomes large. Furthermore, traditional gradient search techniques are typically inappropriate because the solution space is likely to be non-convex. Gradient search techniques tend to converge to a local optimum dependent on initial conditions and are unlikely to find global optimum.

Heuristic optimization techniques have been applied to problems where complete enumeration of the solution space is unrealistic due to the size of the problem and where gradient search techniques fail, due to the objective function not achieving the necessary convexity requirements. Heuristic algorithms typically use intelligent programming or randomness to establish rules to accept inferior solutions that allow the algorithm to extract itself from local optima and explore a larger subset of the entire solution space. In most large problems where heuristic programming is appropriate, global optimality of the heuristic solution cannot be assured. However, heuristic techniques have been applied to large computationally solvable problems and have been shown to identify “good” (i.e. close to the globally optimal) solutions at low levels of computational effort. Several different heuristics optimization techniques have been developed including simulated annealing, tabu search, and genetic algorithms. Heuristic optimization techniques have been gaining favor in forest management applications, most notably Session’s (1993) work with SNAPII, and Bettinger et al. (1997, 1998) and Boston and Bettinger’s (1999) work on maximization of timber production with aquatic and wildlife habitat constraints.

We used simulated annealing (SA) in our analysis. SA uses a random acceptance criterion to allow the algorithm to accept inferior solutions to the optimization procedure. By allowing inferior solutions to enter the solution space, SA is able to explore a larger set of the solution space than traditional gradient search techniques that would be likely to converge to local (non-global) optimum. Simulated annealing uses a temperature parameter and a cooling schedule to initially accept a large number of non-improving solutions. As the temperature is cooled the probability of accepting inferior solutions is reduced to zero.

The objective function we used is the sum of the number of source breeding sites in each of the 10 decades minus two penalty functions. Penalty 1 reduces the score of solutions that do not meet the total volume constraint. Penalty 2 is structured to penalize solutions with total source sites in individual decades less than an established level.

$$\text{Habitat Score} = \Sigma \text{ Source breeding sites} - \text{Penalty 1} - \text{Penalty 2.}$$

$$\text{Penalty 1} = \text{Volume dependent constant / SA temperature parameter.}$$
$$\text{Penalty 2} = \Sigma \text{ (\# of source sites less than established goal)}^2$$

During simulation experiments it was found that at lower harvest volumes a smaller constant in the numerator of Penalty 1 produced better results than higher constants. As the harvest volume constraint was increased we were less likely to find feasible solutions at the lower constant levels. Therefore, the constant in the numerator of Penalty 1 was increased with the harvest level so that the algorithm was likely to find feasible solutions. The denominator in Penalty 1 creates lower penalty values in the early stages of the optimization allowing a more liberal search of the entire solution space. As the temperature parameter decreases the size of Penalty 1 increases making infeasible solutions less attractive in the late stages of the optimization. Only feasible solutions are presented in the following tables (Penalty 1 = 0), and thus all solutions are in the same scale for all harvest volumes.

Penalty 2 acts to smooth the number of source sites in each decade. Initially an objective function of a simple 10 decade sum of source sites was tried. As harvest volumes were increased in these simulations the algorithm would reserve all source sites from harvest until the last decade at which time the number of source sites required to reach the volume constraint were harvested. Thus the algorithm was only penalized 1 point for each unit harvested in the last decade despite creating a significant risk to species survival in the last decades. We, therefore, desired to identify a penalty structure to encourage a relatively stable number of source breeding sites. The following penalty was created:

$$\text{Penalty 2} = \Sigma \text{ (40- number of source sites in a decade if less than 40)}^2$$

This quadratic penalty structure imposes a strong penalty for large deviations from the identified source site goal and imposes a small penalty for small deviations from the established goal (no penalty is imposed if the goal is achieved). The goal of 40 source sites per decade was established from the static analysis of landscape indices. It appeared that there was little risk of species extirpation on static landscapes with 40 or more initial source sites.

Figure 2 shows the basic structure of the simulated annealing algorithm used to solve this problem. Parameterization of the initial and final temperatures, cooling schedule and number of iterations per temperature are established on a problem-by-problem basis in simulated annealing. Several different parameter levels were tested for solution quality. The following parameters were identified as producing the highest objective function values of those parameters tested: initial temperature = 150, final temperature =.1,
cooling =.65 * previous temperature, iterations=15,000.

Timber Harvest and Species Survival Results

Once landscape trajectories over the study time period are found, this solution is fed into PATCH, which simulates the probability of species survival. We also calculate timber harvest volume. Plotting solutions for various levels of the timber harvest constraint we can trace out a frontier that comes close to the production possibility frontier.

Application of the Model to the Central Cascades Region

The time horizon for the current analysis is 100 years, with management activities occurring once each decade. On each management unit in each decade a management decision on whether to harvest or not is made. Timber stand growth and harvest yield are governed by relationships developed for Douglas fir and western hemlock stands in western Oregon (Curtis et al. 1981). Within the GIS image, coniferous forests are divided into 20 year age classes. Every second decade we update the age class on a unit by one, assuming there has been no harvest on the unit in that time interval. For simplicity, we define management units so that they correspond to spatial units used in the species population simulation module, which is a 17 hectare hexagon.

The study area is a 1.2 million hectare GIS image developed by Cohen (1995) of the Central Cascade region in Oregon that includes the Willamette National Forest. Population simulations were conducted on 50 randomly selected 62,500 ha sub-units of the Central Cascade image. The choice of this size analysis unit included consideration of several factors. Most importantly, we wish to have a landscape of sufficient size so that population persistence is not limited due to the number of territories. However, as stated previously, the size of the harvest-scheduling problem is exponential with the number of harvest units. Therefore, it is desirable to have a landscape that will have a relatively low number of harvest units when conducting the optimization process.

For this study we use a hypothetical wildlife species that is characterized by long life and low fecundity with a preference for older coniferous forests. In the future, we plan to parameterize the PATCH model to simulate species with combinations of small versus large body size, that are short versus long distance dispersers, and that are generalists versus specialists.

Simulation Results

We report results for a single initial landscape. The characteristics for this landscape are as follows:

- The landscape includes approximately 700 of 3800 units that meet the minimum 50% conifer constraint and are therefore, available for harvest.

- There are 23 initial source breeding sites with a total of 72 initial breeding sites on this landscape.

- There are 97 potential source breeding sites during the 100 year simulation.

We ran twenty simulations (2 sets of 10) at each harvest volume. The solution with the highest objective function of the set of 10 simulations at each volume was saved (2 solutions at each volume). Ten landscape maps were created from these resulting harvest schedules within PATCH (one for each decade). These maps were created from the original landscape image and represent the characteristics of the landscape each decade resulting from timber growth and scheduled harvest. We ran 100 wildlife population simulations of 100 years on each set of images with the wildlife species parameters in PATCH.

Table 4 shows the output from the simulated annealing algorithm and the corresponding simulation runs with graphical representation presented in Figure 3. Figure 3 represents a feasible production relationship between timber harvest and wildlife population persistence on the specified landscape. Timber harvest significantly competes with wildlife population survival at total 100 year harvest levels between 2.05 million mbf and 2.25 million mbf. At harvest levels below 2.0 million mbf solutions can be identified that do not result in the harvest of any of the source breeding sites. At these levels population survival is very high and is constrained primarily by the initial number of breeding sites on this landscape. At harvest levels greater than 2.25 million mbf population persistence is unlikely due to a majority of source breeding sites entering the harvest solution.

Figure 4 shows the relationship between the objective function score and harvest level. Variation in the objective function increases at higher harvest volumes. This result is likely due to the quadratic penalty function (Penalty 2) that dominates solutions with very high harvest volumes. Additionally, several solutions at the higher harvest volumes resulted in non-feasible solutions (the solution did not meet the harvest volume constraint).

Discussion

Due to the life history parameterization, the wildlife species used in the application in this paper can survive on an intensively managed landscape if a sufficient number of very high quality sites (source breeding sites) are maintained. The number of source breeding sites was the key determinant to species survival probabilities. Limited analysis was conducted to determine if the spatial location of a source site relative to nearby source sites was an important factor in determining the contribution of the site to overall population survival. It did appear that sites that were more than 10 units from their nearest neighbor were less likely to contribute to species survival than those units with neighbors less than 10 units away. Therefore, a spatial aspect that would discount source sites more than 10 units removed may improve solution quality. However, due to the inherent clumpy nature of the source site locations on the landscape we decided to postpone inclusion of this type of spatial component for future research.

In future work, we will explore different species with potentially more complex habitat objective functions. For different life history parameterizations, it is possible that different landscape features other than the number of source breeding sites will turn out to be most important. In addition, we plan to examine landscape management with multiple species, possibly with competitive habitat requirements, to examine tradeoff relationships among these species as well as between species and timber harvest volumes.

In the analysis conducted so far, we took as the economic objective total timber harvest volume over the 100 year period. Under this objective, there is no economic penalty for widely fluctuating harvest volumes (though there may be low species survival if there is little remaining habitat in some time period). Economic considerations such as downward sloping stumpage demand or costs of adjusting the levels of labor and capital in production would induce a penalty to fluctuations in harvest volume. However, due to the relatively small size of the landscape analyzed, a downward sloping stumpage demand curve is unrealistic. If we were to examine a larger landscape a downward sloping stumpage demand function may be appropriate. Also, using total timber harvest over time as the objective also assumes there is no penalty for delaying harvests as there would be positive discounting. In future work we plan to incorporate discounting and downward sloping demand.

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TABLE 1 Variable Definitions

RUN	Simulation run number.
N0	Number of 100 runs when final population >0.
LNP0	Logistic transformation of N0.
STS	Number of breeding sites identified by PATCH.
STS.1	Number of expected source breeding sites (PATCH).
LNST1	Log of STS.1.
LMBD	Sum of the expected dominant eigenvalues of all breeding sites.
LM.S	LMBD/STS.
LMB.1	Sum of the expected dominant eignevalues for all source sites.
L1.S1	LMB.1/STS1.
ST1.ST	ST1/STS
AREA	Area of all pixels qualifying as wildlife habitat.
WEIGHT	Number of habitat pixels times their weighted values.
EDGE	Length of habitat area edge.
CORE1	Habitat core area at least 1 pixel from non-habitat.
FRAC	Fractal dimension.
SHAPE	Landscape shape index.

TABLE 2 Selected logit regression results

LNP0 ~ STS + ST.1 + LM.S + L1.S1 + ST1.ST + AREA + WEIGHT + EDGE + CORE1 + FRAC + SHAPE

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-58.9062	38.9087	-1.5140	0.1383
STS	0.0334	0.0261	1.2801	0.2083
ST.1	0.0670	0.0633	1.0584	0.2965
LM.S	26.8439	37.7022	0.7120	0.4808
L1.S1	26.9698	18.4234	1.4639	0.1514
ST1.ST	6.8831	7.1036	0.9690	0.3387
AREA	0.0000	0.0000	0.5965	0.5544
WEIGHT	0.0000	0.0000	-0.6448	0.5229
EDGE	0.0000	0.0001	-0.2116	0.8336
CORE1	0.0000	0.0000	-0.6420	0.5248
FRAC	-9.0854	13.7120	-0.6626	0.5116
SHAPE	0.0160	0.0827	0.1934	0.8477

Residual standard error: 1.02 on 38 degrees of freedom
Multiple R-Squared: 0.8698
F-statistic: 23.07 on 11 and 38 degrees of freedom

LNP0 ~ ST.1

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-2.8848	0.3155	-9.1449	0.0000
ST.1	0.1395	0.0095	14.6275	0.0000

Residual standard error: 1.076 on 48 degrees of freedom
Multiple R-Squared: 0.8168
F-statistic: 214 on 1 and 48 degrees of freedom

LNP0 ~ AREA + WEIGHT + EDGE + CORE1 + FRAC + SHAPE
Coefficients:

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	11.1679	9.6761	1.1542	0.2548
AREA	-0.0001	0.0001	-2.2145	0.0321
WEIGHT	0.0000	0.0000	3.0577	0.0038
EDGE	0.0002	0.0001	1.8328	0.0738
CORE1	0.0000	0.0000	1.0453	0.3017
FRAC	-10.6493	25.4907	-0.4178	0.6782
SHAPE	-0.2449	0.1510	-1.6214	0.1122

Residual standard error: 1.968 on 43 degrees of freedom
Multiple R-Squared: 0.4511
F-statistic: 5.891 on 6 and 43 degrees of freedom

LNP0 ~ STS + ST.1 + L1.S1

	Value	Std. Error	t value	Pr(>|t|)
(Intercept)	-30.3906	18.5362	-1.6395	0.1079
STS	-0.0141	0.0076	-1.8484	0.0710
ST.1	0.1752	0.0237	7.3805	0.0000
L1.S1	26.4847	17.5728	1.5071	0.1386

Residual standard error: 0.9989 on 46 degrees of freedom
Multiple R-Squared: 0.8488
F-statistic: 86.06 on 3 and 46 degrees of freedom

LNP0 ~ LMB.1 + ST1.ST

	Value	Std. Error	t value	Pr(>|t|)

```
(Intercept)  -4.7724   0.6871    -6.9453   0.0000
      LMB.1   0.1151   0.0099    11.6828   0.0000
     ST1.ST   8.6973   2.8506     3.0510   0.0037

Residual standard error: 0.986 on 47 degrees of freedom
Multiple R-Squared: 0.8495
F-statistic: 132.6 on 2 and 47 degrees of freedom
```

LNP0 ~ LMB.1

```
               Value Std. Error  t value Pr(>|t|)
(Intercept)  -2.8685   0.3116    -9.2060   0.0000
      LMB.1   0.1316   0.0089    14.7693   0.0000

Residual standard error: 1.068 on 48 degrees of freedom
Multiple R-Squared: 0.8196
F-statistic: 218.1 on 1 and 48 degrees of freedom
```

TABLE 3 Correlations coefficients for selected variables

	RUN	N0	LNP0	ST.1
RUN	1.000	-0.031	0.048	0.050
N0	-0.031	1.000	0.946	0.893
LNP0	0.048	0.946	1.000	0.904
N5	-0.026	0.993	0.962	0.898
LNP5	0.050	0.944	0.989	0.885
N10	0.007	0.958	0.974	0.911
LNP10	0.031	0.939	0.983	0.900
STS	0.030	0.806	0.754	0.907
ST.1	0.050	0.893	**0.904**	1.000
LNST1	0.003	0.880	0.844	0.941
LMBD	0.033	0.815	0.766	0.917
LM.S	0.018	0.596	0.641	0.540
LMB.1	0.052	0.893	**0.905**	**0.999**
L1.S1	0.043	0.288	0.333	0.212
ST1.ST	0.022	0.586	0.642	0.545
AREA	0.222	0.428	0.380	0.531
WEIGHT	0.174	0.627	0.555	0.733
EDGE	0.266	-0.030	-0.001	0.040
CORE1	0.118	0.590	0.509	0.688
FRAC	0.209	0.418	0.384	0.543
SHAPE	0.206	-0.428	-0.348	-0.422

TABLE 4 Simulation Results of Model Output

#	Harvest Volume	Habitat Score	Pr(Survival)
1	2.05	-194	.80
2	2.05	-232	.85
3	2.10	-601	.53
4	2.10	-568	.50
5	2.15	-1191	.27
6	2.15	-1057	.25
7	2.20	-1410	.10
8	2.20	-1660	.06

Table 5 Decadal Harvest Volumes and Source Site Examples

Decade	0	1	2	3	4	5	6	7	8	9	Total
Solution 1											
Volume (1000mbf)	366	391	259	150	56	43	76	73	282	355	2,050
Source Sites	23	22	36	36	49	48	55	55	61	37	422
Solution 8											
Volume	425	414	247	141	27	51	101	99	288	409	2,200
Source Sites	22	21	30	25	37	36	39	34	34	11	289

FIGURE 1 MODEL COMPONENTS

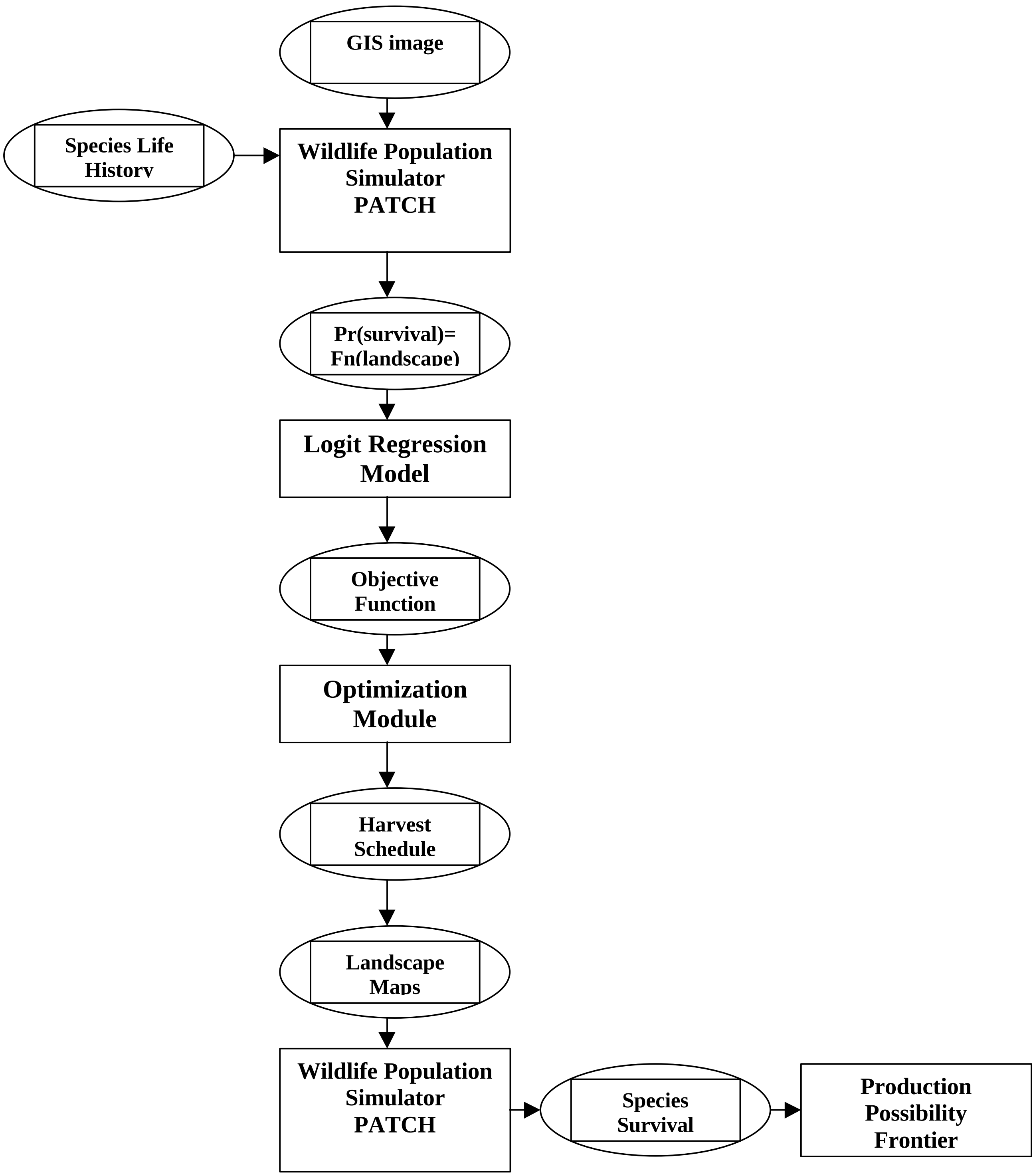


FIGURE 2 SIMULATED ANNEALING FLOW CHART

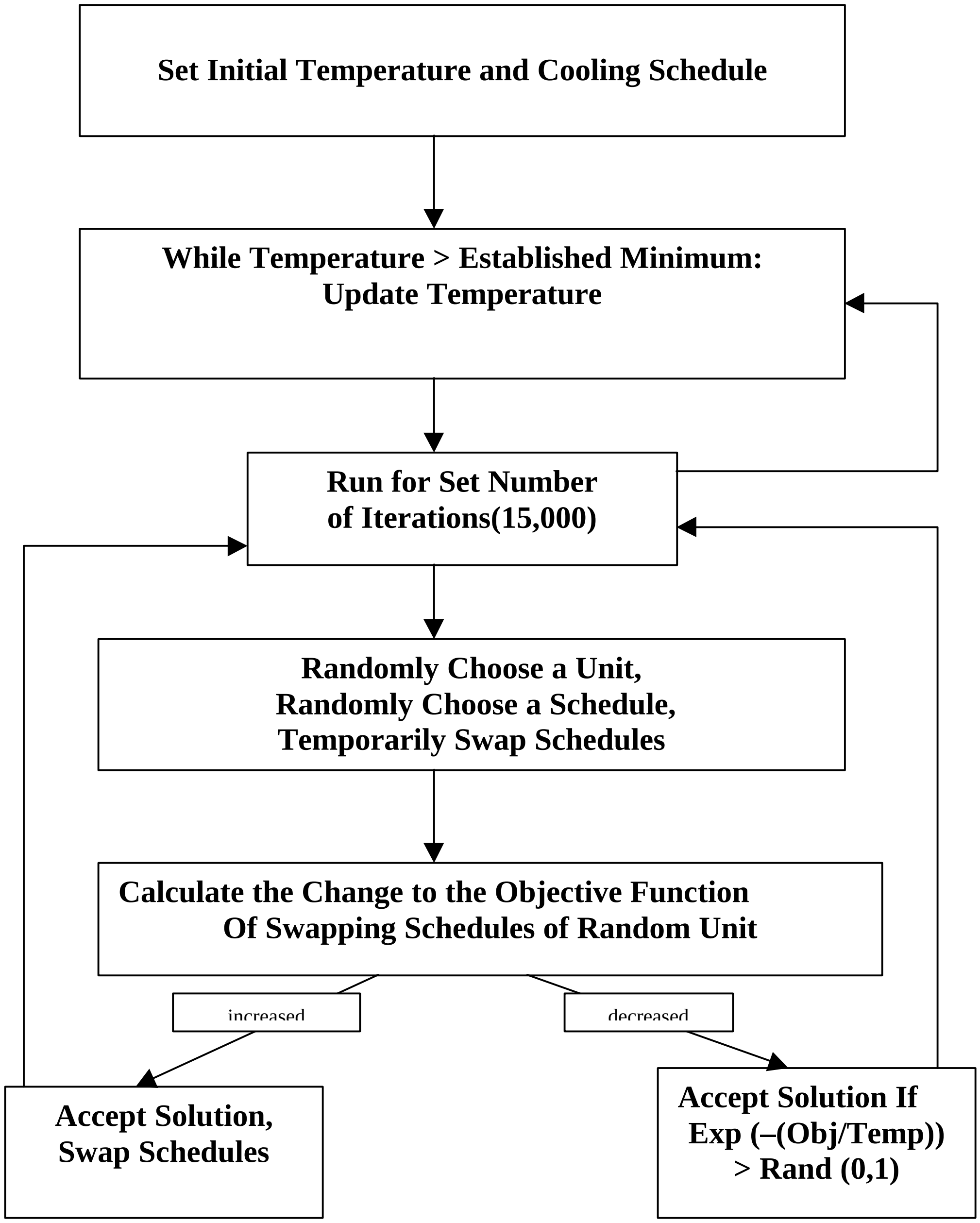
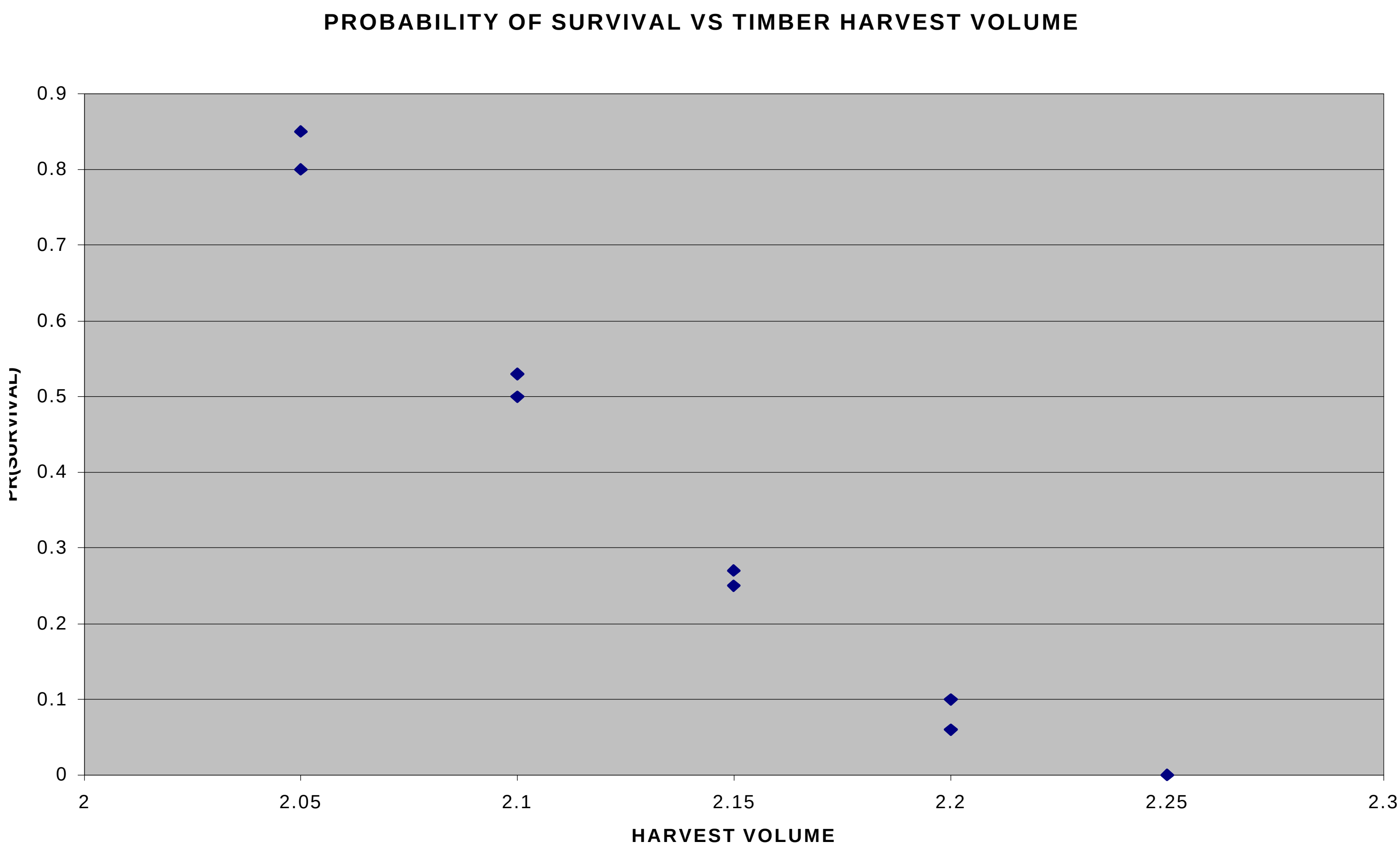
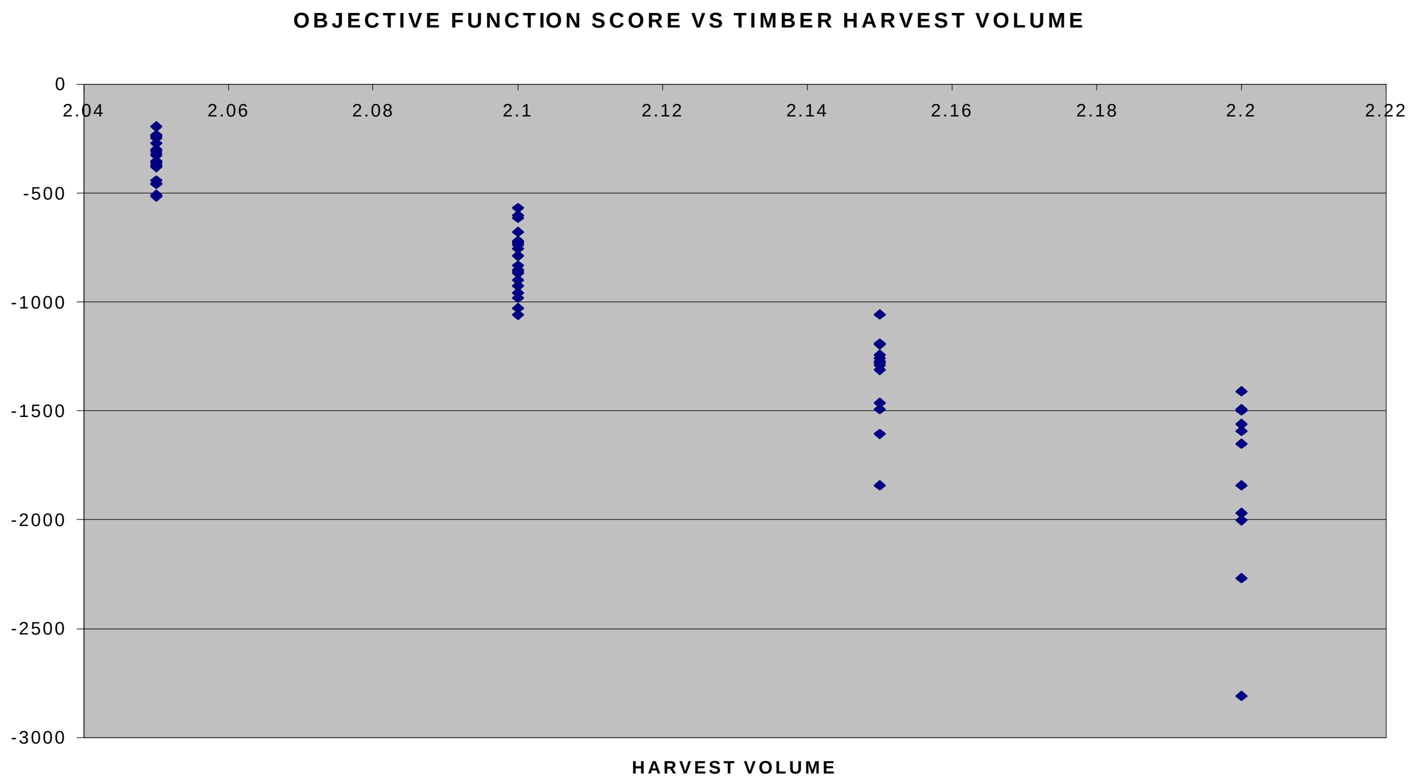


FIGURE 3



PROBABILITY OF SURVIVAL VS TIMBER HARVEST VOLUME
PR(SURVIVAL)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
2.05
2.1
2.15
2.2
2.25
2.3
HARVEST VOLUME

FIGURE 4


OBJECTIVE FUNCTION SCORE VS TIMBER HARVEST VOLUME
0
-500
-1000
-1500
-2000
-2500
-3000
2.04
2.06
2.08
2.1
2.12
2.14
2.16
2.18
2.2
2.22
HARVEST VOLUME

Valuing Outdoor Recreation Effects of Rural Conservation Programs: Constructing Travel Cost Models When Recreational Sites Are Ill-defined

Daniel Hellerstein, USDA, Economic Research Service B Summarization

Dr. Hellerstein's presentation is made in light of the growing importance of land conservation programs, such as the U.S. Department of Agriculture (USDA) Conservation Reserve Program (CRP). A basic premise behind this program is that it is desirable to ameliorate the negative impacts of agriculture. Rural conservation programs such as the CRP can have substantial effects on outdoor opportunities, effects whose value can be measured using non-market valuation techniques. For example, such programs can ameliorate bad agricultural practices that can muddy waters, and lower fishing and swimming quality of waterways. Dr. Hellerstein's analysis focuses upon the CRP, but the problems in analyzing the CRP (e.g., heterogeneity and dispersion) are likely to be present in a number of other rural conservation programs.

Dr. Hellerstein provided a summary for his talk, noting that he would discuss the impacts of agriculture on the rural environment, how federal programs modify these impacts, how the CRP and "environmental targeting" improves the rural environment, and finally some methodological issues of their study.

Dr. Hellerstein made the assertion that agriculture is a natural resource-intensive activity. In the lower 48 states, agriculture accounts for over one-half of all land use, and three-quarters of all freshwater withdrawals. Dr. Hellerstein showed a map illustrating the extent of agricultural lands in the U.S., and noted that 70% of the U.S. population lives in a county in which at least 10% of the county is farmland, and 23% of the U.S. population lives in a county in which at least 50% of the county is farmland. Agriculture affects the rural environment by causing siltation and nutrient runoff, groundwater contamination (it has been estimated that 50 million people live in an area that has some groundwater contamination resulting from agriculture), air quality impacts (the dustbowl effect, to take an extreme example), habitat loss and harm to threatened and endangered species (it has been estimated that 383 species that are listed as threatened or endangered are listed in part because of the effect of agriculture).

A number of federal programs, however, aim to reduce these impacts by encouraging farmers to use environmentally benign practices. Dr. Hellerstein noted that in his ten years of service at USDA there has been an increased emphasis on environmental quality, and that there are a variety of USDA programs that are quite expensive. Also, some USDA agricultural support programs condition receipt of government support payments on compliance with conservation objectives, such as the Swampbuster law.

USDA spends a great deal on land set-asides, the largest of which is the CRP. The CRP was established in 1985 and currently covers about 30 million acres (about 10% of cropland acres) and costs about $1.3 billion per year. The CRP typically pays a farmer 50% of the cost of establishing some perennial cover, and also gives the farmer an annual rental payment. In exchange, the farmer is expected to idle the land for ten to fifteen years, after which the land much more resembles a natural state in which there is less erosion and more habitat for naturally occurring species.

Dr. Hellerstein showed a map of CRP lands as of 1992, which is not much different from a map of how it looks today. Dr. Hellerstein noted that most of the CRP lands are in places where land is inexpensive, raising the question of whether this is a good criteria by which to award CRP funds. Maximizing the benefits of the CRP may well improve the environmental performance of the CRP, giving rise to the environmental targeting method, in which some judgment is made as to how valuable the agricultural land is as set-aside.

The goals of the CRP include:

- reducing soil erosion, which was the main focus of the CRP when the program was initiated in 1985,
- reducing sedimentation,
- improving fish and wildlife habitat,
- providing income support for farmers (this was a much more salient goal in 1985),
- protecting soil productivity,
- improving water quality, and
- curbing the production of surplus agricultural commodities.

The results of Dr. Hellerstein's April 1999 study examined how environmental targeting could be used in the CRP to provide greater environmental benefits, and more outdoor recreational opportunities. The study is titled "Economic Valuation of Environmental Benefits and the Targeting of Conservation Programs: the Case of the CRP," by Peter Feather, Daniel Hellerstein and LeRoy Hansen (USDA AER #778, http://www.econ.ag.gov/epubs/pdf/aer778). Environmental targeting is defined as "... the practice of directing program resources to lands where the greatest environmental benefit is generated for a given expenditure, or alternatively, specific environmental goals are achieved for the least cost." Or, it can be stated more simply as getting the biggest "bang" for the buck.

Where can we invest the $1.3 billion so that we maximize the environmental benefits, or more importantly, where can it be invested so that it can benefit people the most? So the study asks the question, "what happens when alternative mechanisms are used to allocate land to the CRP?" In particular, the study examines the impact of the CRP on outdoor recreation. There are two forms of environmental targeting: first, using the original 1985 erodibility criteria, essentially assigning most CRP lands to erodible lands, and second, using the Environmental Benefits Index (EBI) used in the 1997 sign-up of the CRP. Using the EBI, farmers offer parcels of land for enrollment under the CRP, and each parcel is rated on different attributes of environmental value, such as cost, erodibility, soil leachability, proximity to water bodies, and measures of locally affected populations. Since more land is offered by farmers for participation in the CRP than there is money to accept, parcels are accepted on the basis of some index. The EBI is one such index.

Dr. Hellerstein's study focused upon three recreational activities: (i) freshwater-based recreation, (ii) wildlife viewing, and (iii) pheasant hunting. These activities are important, and are also conducive to analysis that uses revealed preference techniques. Other CRP benefits such as duck hunting, and improvement of habitat for endangered or threatened species may be very important but are hard to measure because of the lack of revealed preference data.

The study's primary results were that switching CRP targeting criteria from erodibility to the EBI approximately doubles the benefits of freshwater-based recreation and wildlife viewing. CRP wildlife recreation benefits are significantly larger than freshwater-based recreation benefits. The study also found that population should be considered when targeting CRP lands, an aspect that had previously been accounted for only indirectly. Finally, the study concluded that valuation-based targeting of the CRP is feasible and may improve the environmental performance of the CRP.

Using an EBI instead of an erodibility index for targeting CRP lands results in an increase in estimated benefits of $92.5 million (from $36.4 million to $128.9 million) for freshwater-based recreation, and an increase of $287.4 million for wildlife viewing (from $347.7 million to $635.1 million), and a decrease of $10.1 million for pheasant hunting (from $80.2 million to $70.1 million). This is out of a total of about $30 billion in freshwater-based recreation, $6 billion for wildlife viewing. Dr. Hellerstein noted that this might be considered a substantial though not very large portion of the total value of these forms of recreation.

Dr. Hellerstein then began discussion of the methodological issues associated with the study. In order to model the impact of the CRP on outdoor recreation, behavioral data is needed to ascertain how people use the rural environment for outdoor recreation. Also, biophysical data is needed to help measure the features of the rural environment that might affect outdoor recreation. Also, data is needed as to where people visit to link behavioral data to biophysical data. Finally, demand models are needed to predict how changes in land uses impact the value, which can generate estimations of surplus and allow the welfare analysis that is needed to assess the CRP.

The broad geographic dispersion of the CRP complicates this analysis, in that the CRP does not change a particular site, and the individuals visiting these sites are not highly committed to visiting these sites. Also, some CRP programs change the quality of many recreational sites. Both of these factors make all four of the analytical steps for conducting welfare analysis more difficult.

Behavioral data answers the question: "what is the American public's use of rural environment for outdoor recreation?" The behavioral data used consisted of the 1992 National Survey of Recreation and the Environment for water-based recreation, which consisted of 1500 respondents; and the 1991 Fishing, Hunting and Wildlife Associated Recreation Survey for pheasant and wildlife, which consisted of 22,000 hunting and fishing respondents and 23,000 other respondents who engaged in non-consumptive uses. The former survey was fairly detailed in that a serious attempt was made to identify where people visited. On the other hand, the latter survey was fairly thin on where people visited, but consisted of count data on the number of trips that were taken by each respondent. So the latter data base was larger but required more econometric manipulation.

Biophysical data is needed to answer the question: “how do changes in land use influence environmental quality?” The data used for all three models were derived from the 1992 National Resources Inventory, developed by the Natural Resources Conservation Service, which consists of an 800,000 point sample, and includes information on over 100 variables, including land use, vegetative cover, and soil type. This information does not say very much about water quality or wildlife, and sometimes does not identify location very well.

Data on where people visit is needed to answer the question: “how to determine influence of environmental and socioeconomic characteristics on the recreational uses of the rural environment?” Aggregated sites were used. Thus, rather than interpreting data as an individual visited a particular site, the data is aggregated to reflect the assumption that individuals visited some county or sub-county. The hope is that the characteristics of sites within a county or sub-county are relatively homogeneous.

For the freshwater-recreation model, 14,400 sub country areas, or NRI polygons, were used. For the pheasant hunting model, sixteen semi-circular “quadrants” were drawn around each respondent, and the attributes of each zone were measured. For the wildlife viewing model, nineteen semi-circular “quadrants” were drawn around each respondent. Dr. Hellerstein presented a graphical illustration for each set of geographical units.

Characteristics of aggregated sites were determined using NRI point data and information gathered using Geographic Information Systems surface techniques to determine the fraction of land in the CRP. To determine what aggregated sites were visited, there was a common problem in determining exactly which aggregated site was visited. Ancillary information on site names was used to determine the NRI polygon visited. Where the respondent did not know the site name, she was asked if she knew how far and what direction the site was. For the pheasant hunting model, an indicator function based on the breeding bird survey was used to determine the correct quadrant. For the wildlife-viewing model, flexible aggregation, was used to create quality and price indices.

For modeling demand, a two-stage discrete/count model was used to model demand of water-based recreation, and consumer surplus was computed using the count of trips made. A two-stage discrete/count model was also used to model demand for pheasant hunting trips. A gravity model was used to model demand for wildlife viewing trips, and consumer surplus was computed using a benefit transfer analysis of per-trip values.

The study concluded first, that it is possible to value the impacts of changes in the rural environment on outdoor recreation; second, that targeting the CRP can substantially increase the benefits generated by several outdoor recreational activities; and third, that determining the site visited in data sets such as the ones used in this study requires careful consideration.

Policy Discussion of Session Two

Katherine Smith, USDA, Economic Research Service B Summarization

Perhaps the most important lesson that the presentations provide is that when discussing issues of rural land use policy, context is very important. When one considers the variety of contexts in which policy can affect land use decisions, the decision-making process becomes quite complicated. Dr. Smith thus adopts a land use designation by one of four types of values or goods produced from the land: goods of commercial value, recreational and related values, option or existence value, and development value (see Table 1: Policy Influences on Rural Land Values).

With respect to land that produces goods of a commercial value (typically agricultural products), the goods are generally of a private nature, accruing mostly to the benefit of local farmers, yet policies affecting the value of such goods are generally not local. While there are some local policies pertaining to nuisance law and right-to-farm laws, federal agricultural policies affect the value of these goods much more. In addition to federal agricultural policy, state and federal environmental policy and tax policy have a significant influence on these values, by affecting the net returns from agricultural activity. Thus, although the value affects local farmers, the policies affecting the value are typically of a national or state level, possibly giving rise to a disconnect between the site of the value of the goods and the site of the policy-making.

For lands that yield recreational and related values, the goods can take on a variety of natures. The goods can be private and local, private and valued by a distant (urban, for example) population, club goods (which may be local or distant, but are typically non-rival insofar as a group is able to exclude all others), or public goods (which may be local or distant, but are both non-rival and non-excludable). Recreational and related land use value is affected by state and federal environmental laws such as the Endangered Species Act, but also by federal policies, which have been used recently to preserve rural amenities. The rural amenity preservation use of national agricultural policy has been notable lately because it is sometimes claimed in the international trade arena to be a barrier to trade, a topic of considerable controversy as evidenced by the World Trade Organization protests in Seattle. Recreational and related land use value is also affected by local zoning policy. Thus, there are several different levels of policy that can affect recreational and related use values. Which is “best” to use, or how policies unrelated to recreational use value might need to consider implications for that use value, are the kinds of questions that attention to the context of the land use policy raises.

A third set of values produced by rural land is option or existence value as open space, which is the value of the option of retaining the land as open space, since development of the land is irreversible. Existence value is the value of knowing that the land is preserved in an open space state, even if one does not plan to visit the land and use it. These values reflect public goods, and also luxury goods because they are things which are valued more as income increases. Dr. Smith thus hypothesizes that the option and existence values of land as open space are centered in urban areas, where income is greater and more concentrated. The value is thus distant from the land itself. Although some federal environmental policies affect option and existence value, the more typical policy intervention affecting these nonuse land values involves local zoning laws. This again suggests the potential for a big gap between the beneficiaries of the open space and those who enact the policies that affect it.

The fourth type of value that might be produced by a single parcel of land that also has agricultural use, recreational use, and option and existence values, land is value directly related to its potential developed use. Development of land is highly path-dependent, and as Dr. Bockstael's work illustrates, is influenced greatly by nearby land that is used in similar ways. The development value of land is privately held and locally observed. But because the development value of land is affected both by relative spatial and intertemporal dimensions, this land value is influenced by all of the policies that affect all three of the other types of values -- agricultural use value, recreation use value, and option and existence value. This is why when one asks about the federal role in rural land use policy, or the appropriate level of government for addressing sprawl or farmland preservation issues, it is very difficult to come up with a simple answer. Given the spatial and temporal interactions demonstrated by several of the papers presented in this session, and the potential differences between the initiators and beneficiaries of land use policy as outlined by Table 1, it is clear that more conferences of this type are needed to further discuss the types of policies that are appropriate and effective in governing rural land use.

Table 1: Policy Influences on Rural Land Values

Rural land value	Realized as…		Influenced by…	
	Type of good	Proximity	**Type of public policy**	Geopolitical level
Commercial agricultural use	Private	Local	Farm legislation Environmental regs. Nuisance; Right to Farm Tax	Federal Federal, State Local State, Local
Recreational and related use	Private Club Public	Local; Distant Local; Distant Local; Distant	Farm legislation Environmental regs. Zoning	Federal Federal, State Local
Option and Existence	Public	Distant; Local	Some environmental (e.g., Endangered Species Act) Zoning	Federal Local
Potential developed use	Private	Local	All of the Above	

Policy Discussion of Session Two

By Brian Heninger, US EPA, Office of Economy and Environment

I want to begin by briefly describing my own background and perspective on land use policy and economic analysis. While my main area of research at the EPA has been in air quality issues, I also have a background in land use issues from teaching Land Economics at the University of Massachusetts in Amherst for two years, and at the University of Connecticut I did research into landowners knowledge and attitudes about the preservation of their privately owned forested and other undeveloped land. I will draw upon these experiences through out my talk.

I applaud the contributions of the three papers and want to begin by briefly describing the very different approaches each of the authors used in discussing economic analysis and land use policy. Nancy Bockstael's paper took the approach of trying to explain land use patterns and discussed the lessons we can learn from this analysis, while Stephen Polasky's paper focused on how to efficiently pursue multiple land uses on the same parcel of land by balancing economic and ecological goals. The third paper by Daniel Hellerstein looked at valuing the multiple recreational effects of the Conservation Reserve Program (CRP). The three papers taken together help to increase our understanding of the value of open space, how to preserve it and how to use it efficiently.

First, I would like to provide a brief synopsis of the three papers. Beginning first with the paper presented by Nancy Bockstael, "Changing Land Use Patterns at the Urban-Rural Fringe," I agree with the authors of the importance of incorporating "interaction effects" into the model, as it leads to predicting very different patterns of land use conservation (than plain monocentric models). I also find the adaption from interacting particle system theory extremely interesting. One of the policy implications from this work are better insights into the repelling and attracting influences of development, as described in Dr. Bockstael's presentation. The negative externalities of denser development has to balance with the increased transportation costs of getting around and the increased difficulty of being supplied with public services. The "tug of war" between these repelling and attracting influences is where policy makers can have their influence. For example, I am an avid researcher and proponent of increased gasoline taxes for the control of air quality. I want to emphasize that this policy tool can have impacts on land use, as an increase in these taxes will not only have the short run effects of decreasing the average yearly miles traveled by individuals, but it will also have the longer run effects of influencing individuals' and businesses' locational choice, leading to denser development patterns. Another example of a policy relevant tool to this paper is zoning. More zoning rules or increased enforcement of existing zoning rules can reduce the negative externalities of denser development patterns.

Stephen Polasky's paper dealt with reconciling conflicting economic and ecological goals on a parcel of land. He developed a modeling framework to trace out the production possibilities frontier between a species survival and timber harvest. This gives us the efficient combinations of wildlife population and value of timber harvest. Future work could incorporate multiple species and more complex habitat objective functions. Multiple use is an increasingly popular land use objective. With this comes increasing conflicts; between economic type goals such as recreation; e.g., cross country skiers vs. snowmobilers or between ecological goals, such as species populations; e.g., wolves vs. elk.

The paper presented by Daniel Hellerstein focused on valuing the multiple benefits (particularly recreation benefits) of the Conservation Reserve Program (CRP.) The CRP encourages planting of protective cover, grasses, trees, buffers, wildlife habitats etc. It is a voluntary program where the participating landowners can get annual rental payments, utilize incentives and take advantage of cost sharing. This represents the costs of the program, while the benefits of the program are: water quality protection, erosion prevention, protection of wildlife habitat and much more. The program can even use "environmental targeting" since the number of applicants for entrance into the program is greater than the available openings. This allows the program managers to rank applicant's land based upon its characteristics and its location, so the land is where people want it and where it can provide the most benefits. Valuing these multiple benefits of land uses encouraged by the CRP is important to justify the program.

However, EPA has a limited set of tools to directly affect land use patterns. Most land use decisions are decided locally. National lands are managed by the Department of the Interior, or the Department of Agriculture, which also influences land uses of agricultural land through its policies. However, EPA can indirectly affect land use in a variety of ways. It can promote its agenda through regulations which indirectly influence land use, or through partnerships with other federal agencies, states, localities, industry, and civic groups. EPA is also often involved with funding research which helps us better understand our environment and land.

Sometimes the relevant policy tool is education. In the state of Connecticut, 60% of the land is forested, and 88% of that forested land is what is termed non-industrial private forests or land owned by regular folk. Forty two percent of the forested parcels in the state are less than 50 acres and 21% are less than 20 acres. The average age of a forest land owner in the state is over 60. So, as land is passed on to multiple heirs, it is often split up into several sub-parcels. And even when all the heirs agree that they would like to keep the whole parcel of land forested and protected, it is often not possible as, escalating land prices in the 1980's have caused the amount of estate taxes owed on the land to be extremely high. Surveys show that many heirs are unprepared or unable to pay these high estate taxes and are forced to sell their land or a portion of their land just to pay their estate taxes. This all too common situation causes the further fragmentation of forest land in the state. Several other states are likely to be in the same situation as Connecticut. The average value per acre of forest land decreases as fragmentation occurs, since larger tracts of forests are better for wildlife habitat and the protection of water quality. So, in this case, educating land owners as to how to prepare for estate taxes, and teaching them about the wide variety of conservation tools and options available to them is a useful policy tool to influence private land use.

There is a vast literature on methods to conserve open space. I remember a paper which advocates subsidizing dairy production (supporting milk prices) in New England in order to encourage the positive externalities of open space land used in dairy production. While this type of policy will help to preserve beautiful landscapes, it will also lead to surplus milk, cheese and other dairy products being produced unnecessarily. There are many more direct ways to preserve open space and influence land use.

In closing, I would like to thank the three presenters for their interesting work. Although, their papers were very different from one another, each had its own contribution to make, as to how we think about land, and what role EPA and other regulatory agencies can play in influencing land use and private land use decisions.

Question and Answer Period for Session Two

Molly Espey, Clemson University, asked Dr. Bockstael if she had data on the size of parcels, and if that had any effect on the decision to develop. Dr. Bockstael replied that this data was being analyzed in other work she was doing, and this data was being used along with zoning data to actually predict the value of parcels. In the research presented in this workshop, Dr. Bockstael did not include data on parcel size, but only included parcels that were zoned in such a way that they could be developed.

Kerry Smith, North Carolina State University, asked Dr. Hellerstein about calculating the net benefits of the Conservation Reserve Program (CRP). Dr. Smith noted that in recent years the CRP has been an auction program in that individuals are required to state how much payment they would require to be brought into the CRP. Dr. Smith asked if these bids are the values that are used to calculate net benefits. Dr. Hellerstein replied that the bids were considered a cost for purposes of calculating the Environmental Benefits Index (EBI), and was a fairly important factor in terms of ranking parcels and identifying parcels to be enrolled.

Dr. Kerry Smith asked a second question regarding a comment made by one of the discussants to the effect that EPA does not have a role in land policy. Dr. Smith was hesitant to agree with such a statement, and noted the example of non-attainment areas, and how EPA is responsible for managing the consequences of land use. Although it is currently not the norm to think about land use as a reason for non-attainment, it seems like a natural connection, especially in that non-attainment often simply has to do with the fact that people live in the non-attainment area. Dr. Smith likened the situation to water quality regulation, where we tend to think about point sources and technology-based standards, but that we could as well think of non-point sources and management strategies for an entire watershed. Fundamentally, Dr. Smith proposed meeting a set of more comprehensive goals with a different framework of regulation. Dr. Brian Heninger, US EPA, replied that he did not mean to say that EPA did not have a role in determining land use, but that EPA did not have a large *direct* role in such issues. However, Dr. Heninger agreed that EPA does have a number of indirect tools. For example, the designation of an area as non-attainment does carry with it significant land-use implications, including the location of new facilities or transportation projects.

Katherine (Kitty) Smith, USDA ERS, emphasized that although land use may not be a principal policy goal, federal policy can have a substantial effect on land uses. The important question to be answered now is whether these federal programs with other goals ought to be directed at land use goals. Dr. Bockstael noted that the Chesapeake Bay provides an interesting example, in that there are many different goals for the area, particularly nutrient loading, so tributary strategies and tributary goals have been developed for meeting these goals. These tributary strategies do not align themselves with any political jurisdiction. In looking at these strategies, it is important to realize that generally speaking, there is usually very little any jurisdiction can do to forbid the construction of a house. Subdivision development can be postponed, but usually can’t be prevented, because local jurisdictions have no bases on which to stop development. Rural development, in particular, may pose environmental problems in that when there is no public sewer service, septic systems used in lieu of sewer service leak and exacerbate nutrient loading problems. On the other hand, a Bay Journal article recently reported that the wastewater treatment for the region is close to capacity, so that wastewater treatment may not even be an option. The problem of where to put people becomes a very complicated one, especially since there is this non-alignment of ecological domains, economic domains, and political jurisdictions. Sven Kaiser, US EPA Brownfields Office, added that EPA has traditionally had an end-of-pipe approach, but has looked at changing that approach in favor of a more comprehensive approach. For example, Mr. Kaiser's Brownfields Office is working with the EPA Office of Air and Radiation to look at State Implementation Plans to develop programs where credits can be issued for land uses that are likely to have favorable air impacts. The same thing can be done for water quality regulation, in light of the Total Maximum Daily Load requirements that are being developed by states. Dr. Kitty Smith pointed out that USDA has been doing this for 50 years, providing direct payments to landowners, and noted that there are problems there as well, so that using the local jurisdiction as an arbiter may be effective.

John Miranowski, University of Iowa, asked Dr. Bockstael, in light of her statement that there is little that a local jurisdiction can do to prevent development, if there are control variables for economic incentives in their model that might modify development patterns. Dr. Bockstael replied that this was not considered in this work, but other research she is conducting looks at how these land management tools affect the probability of development. Some of the policy tools that Dr. Bockstael considered include minimum lot-size zoning, provision of public water and sewer services, land preservation programs (Dr. Bockstael's STAR grant research addresses this), and adequate public facilities moratoria. Smart growth is aimed at two things: buying land and removing it from the pool of developable land, and taking away incentives for sprawl development by not investing in infrastructure (including transportation) in places where development is undesirable. These are the policies that are being built into the land use models Dr. Bockstael is working on. The zoning and sewer policy tools, which attempt to make development more expensive, do not seem to be as effective as local public jurisdictions have expected them to be. The desire to leapfrog development out to those areas is so great that these disincentives are insufficient to stall sprawl development. Were Dr. Bockstael able to calibrate her models sufficiently, she might be able to predict the level of disincentive that would be necessary to stall sprawl development. Dr. Bockstael noted that these policies actually have had the opposite effect; for example, large-lot zoning requirements have provided perverse incentives to develop low-density housing. Dr. Bockstael also wondered if we were thinking ahead enough regarding possible new instruments.

Clay Ogg, US EPA Office of Policy Development, complimented Dr. Hellerstein for his work because of its relevance to a program that was already in place. Dr. Ogg noted that Dr. Hellerstein had focused upon the Environmental Benefits Index, and asked if Dr. Hellerstein had looked at continuous sign-up programs, which half of the state agricultural land preservation enrollment programs have adopted. Dr. Hellerstein replied that their research did not look explicitly at this, although it could be incorporated into their model.

David Martin, Davidson College, asked Dr. Bockstael if it was appropriate to incorporate the probability of successful habitat preservation or some environmental benefits index into her model so that it could map out how future development would look if we were being environmentally conscious. Dr. Bockstael replied that this was being incorporated in her other models as part of her current research with a number of ecologists, who are able to identify spatial development patterns that are better for various species. There is currently not a great deal of feedback from this sub-model, because development is not generally located next to the habitat of sensitive species. Dr. Bockstael added that some fragmentation patterns were generally not harmful to some species. Dr. Polasky added that his research considered this, particularly since the forest management model essentially allowed the modeler to play God, so to speak, in terms of being able to prescribe management solutions and trade off timber harvests against species survival. Ideally, species survival information could be fed back into the PATCH model utilized by Dr. Polasky. Dr. Martin also asked Dr. Bockstael if the clustering pattern of development was a reflection of the land simply becoming available for development or if it was the result of utility maximization by landowners. Dr. Bockstael replied that the clustering development pattern was neither occurring randomly, nor as the result of the monocentric central business district model, when tested against the repelling forces model, although the latter test was the focus of her presentation.

Matt Clark, US EPA NCERQA, cited predictions that there will be 100 million more people in the U.S. in the next 50 years, and asked the speakers if they had any ideas of what a model of optimal growth would look like. Dr. Hellerstein responded that even with an additional 100 million people, there will still be very much rural land available, and that the notion that population growth will eat up agricultural land is wrong, except for certain places, such as the Central Valley of California. Dr. Bockstael replied that whether population growth impacts rural land does indeed depend on where you are. The coastal states are experiencing high population growth and are under strong pressures. If land development patterns do not change, there will be dramatic effects. Dr. Bockstael also noted that we are bumping up against constraints such as water quality requirements, which may become even more binding in the future. Dr. Polasky referred to a recent National Academy of Sciences study that discussed big environmental problems and trends over the next 50 years, and one problem the study identified was land use conversions, including but not limited to conversions from agriculture to residential land uses. Dr. Polasky commented that this problem is more pressing in developing countries, both in terms of population growth pressures as well as species richness.

Ted Su, Bureau of Land Management (BLM), commented that federal land management agencies such as BLM should have had something to say about the topic of land management, and that EPA alone will probably be unable to solve complex land use problems. Dr. Su, commented that BLM management emphasizes multiple use and sustainable yield. That is, consider the natural and cultural resources, what is the best way to manage activities such as mineral development and grazing, or in short, what is the best way to manage the land. Dr. Su asked if indeed there is a mathematical solution in which all of the alternatives can be identified and modeled, commenting that such a model would necessarily be complicated. Dr. Kitty Smith commented that one can model multiple objectives over time and space, but that it was difficult to get the right weights, incorporating social preferences.

Dr. Kerry Smith asked Dr. Polasky about the proper measurement of timber output. Dr. Smith noted that Dr. Polasky's model used board-feet, and asked Dr. Polasky if it might not be more accurate to use present value of prices of timber or expected present value of prices. Dr. Polasky replied that it would be easy to put in present value and expected values. One reason that Dr. Polasky's team has not done this thus far is that the objective function is highly sensitive to species breeding patterns. Introducing discounting when the species breeding aspect of the model is not yet highly refined leads to strange results, such as cutting a lot of timber in some time periods. However, Dr. Polasky agreed that looking at dynamic prices would be interesting. A second question posed by Dr. Kerry Smith referred to species interaction effects, and what to do to take into account such effects, since disturbing the habitat of one species necessarily disturbs a number of other species as well. Dr. Polasky replied that even taking into account the simplest predator-prey relationship, the model becomes considerably more complicated. While one way of attacking this problem is to attempt to model a multitude of species, another way is to attempt to address the needs of a "flagship" species such as the grizzly bear, such that by addressing the needs of this species one can be reasonably certain that the needs of a multitude of other species will be addressed as well. A third question posed by Dr. Kerry Smith hypothesized that it is simply impossible to solve these problems in time to influence any policy outcomes, so that a more appropriate question might be one of how much insurance should we buy, or what do we think we need to repair damaged ecological resources? Dr. Polasky replied that we are currently only answering very rough questions of insurance, and that this may give us some idea of where to concentrate resources.

Mary Ahearn, USDA ERS, commented that she was impressed that Dr. Hellerstein and Dr. Polasky were able to actually quantify program benefits. Dr. Ahearn posed two questions: first, given that there is much uncertainty over the economic benefits and costs of programs, how much longer do we have to wait for good information, and second, can we use economic models? Dr. Polasky replied that economists are accustomed to framing things in terms of objective functions, which makes economic models simpler.

Steve Winett, EPA Region 3, asked the speakers about the effects of climate change. Dr. Polasky replied that there is some concern that environmental changes will affect land set-asides. Dr. Hellerstein replied that there is work being done at USDA ERS, but that it is focused on the effects on agriculture. Dr. Bockstael replied that one way of thinking about this question is in terms of rising sea levels and how we protect ourselves and avoid investing in infrastructure that will be under water. Dr. Bockstael commented that the Federal Emergency Management Agency was interested in this work.